AD NO. ___________________________
DTC PROJECT NO. 8-CO-160-UXO-020
REPORT NO. ATC-9931

UXO TECHNOLOGY DEMONSTRATION SITE

ACTIVE SITE SCORING RECORD NO. 932

SITE LOCATION:
U.S. ARMY ABERDEEN PROVING GROUND

DEMONSTRATOR:
ENGINEERING RESEARCH AND
DEVELOPMENT CENTER (ERDC)
3909 HALLS FERRY ROAD
VICKSBURG, MS 39180-6199

TECHNOLOGY TYPE/PLATFORM:
EM63/PUSHCART

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

MAY 2009

Prepared for:
U.S. ARMY ENVIRONMENTAL COMMAND
ABERDEEN PROVING GROUND, MD 21010-5401

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

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J. Stephen McClung		May 2009
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(Return to ATC PAO for further processing)

DTC GO/SES	N/A		

Encl
as

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
April 2009	Final	30 March through 27 April 2009

4. TITLE AND SUBTITLE STANDARDIZED UXO TECHNOLOGY DEMONSTRATION SITE SCORING RECORD NO. 932	**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) McClung, Stephen J.	**5d. PROJECT NUMBER** 8-CO-160-UXO-020 **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Commander U.S. Army Developmental Test Command 400 Colleran Road Aberdeen Proving Ground, MD 21005-5059	**8. PERFORMING ORGANIZATION REPORT NUMBER** ATC-9931
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Commander U.S. Army Environmental Command ATTN: IMAE-RTA (Ms. Kimberly Watts) 314 Longs Corner Road Warren, MI 48397-5000	**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)** Same as Item 8

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution unlimited.

13. SUPPLEMENTARY NOTES
None

14. ABSTRACT

This scoring record documents the efforts of U.S. Army Engineering Research and Development Center (ERCD) to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site blind grid, open field, and active sites. This Scoring Record was coordinated by J. Stephen McClung and the Standardized UXO Technology Demonstration Site Scoring Committee.
Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Command, and the U.S. Army Aberdeen Test Center.

15. SUBJECT TERMS

ERDC, APG, Standardized UXO Technology Demonstration Site, blind grid, open field, active, EM63/Pushcart.

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(Include area code)*
Unclassified	Unclassified	Unclassified	SAR		

ACKNOWLEDGEMENTS

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of munitions and explosives of concern (MEC) - i.e., unexploded ordnance (UXO) and discarded military munitions (DMM) require testing and evaluation in order for their performance to be characterized. It is imperative that this characterization be performed on a realistic test site in order to successfully gauge how well a system may perform at an actual munitions response site. To that end, the Active Response Demonstration Site has been developed at Aberdeen Proving Ground (APG), Maryland. This site provides the ability to test technologies under development on an actual test range that has a large number of UXO, MEC, and DMM that have not been cleared. Realistic characteristics of the Active Response Site include significant quantities of live UXO, range scrap, and excess debris. Testing at this site is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and validating the standardized UXO test sites.

The Active Response Demonstration Site Program is a multiagency program spearheaded by the U.S. Army Environmental Command (USAEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP), and the Army Environmental Quality Technology (EQT) Program.

1.2 SCORING OBJECTIVES

The objective in the Active Response Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under realistic conditions. The only UXO that were cleared before vendors were allowed to survey the area are items that pose a safety hazard.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under a realistic scenario.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine the demonstrator’s ability to analyze survey data in a timely manner and provide prioritized target lists with associated confidence levels.

d. To provide independent site management to enable the collection of high quality ground-truth (GT) and geo-referenced data for post-demonstration analysis.

1.2.1 Scoring Methodology

The Active Response Demonstration Site is divided into 20 meter by 20 meter grids. The grids are ranked based upon the density of items that have accumulated in each respective grid cell. After multiple vendors surveyed the area with their UXO detection/discrimination systems, half of the 2 acre site was cleared of all metallic items. This clearing of the metallic anomalies from the 2 acre Active Response Demonstration Site was broken into three phases. In the first phase, the target lists from all of the vendors that have surveyed the site was combined in order to create a master target list that was used in the initial phase of the site clearance. Once Phase One was completed, a secondary sweep of the site took place and another recovery operation was performed. After the secondary investigation was completed, the Naval Research Lab (NRL) conducted a survey of the site with their Multiple Towed Array Detection System (MTADS). This system is known for its effectiveness and ability to detect metallic items. Once the NRL MTADS surveyed the site, ATC collected their data and conducted another intrusive operation in order to remove any additional anomalies. During each clearance operation, the exact placement of all the metallic items was carefully measured in order to create a GT for each grid cell. Once the GT for each cell was compiled, each item in the GT was classified as being either ordnance or clutter. Clutter items are defined as metallic items that do not have enough explosives to be considered safety hazards. Fuzes that no longer have their boosters, fins, fragmented items, and items that were never part of any ordnance item for example were classified as clutter. The remaining objects that pose a safety risk were classified as ordnance. This GT will be used to score all of the vendors that had previously surveyed the site, prior to clearance.

a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the response stage and discrimination stage. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to clutter items, measuring the probability of false positive (P_{fp}), and those that do not correspond to any known item, termed background alarms.

b. The response stage scoring evaluates the ability of the system to detect targets without regard to ability to discriminate ordnance from other anomalies. This list is generated with minimal processing.

c. The discrimination stage evaluates the demonstrator's ability to correctly identify ordnance as such and to reject clutter. For the discrimination stage, the demonstrator provides the scoring committee with the output of the algorithms applied in the discrimination-stage processing. The values in this list are prioritized based on the demonstrator's determination that an item is ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking is based on human (subjective) judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e., that is expected to retain all detected ordnance and rejects the maximum amount of clutter).

d. The demonstrator is also scored on efficiency and rejection ratio, which measures the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from nonordnance items. Efficiency measures the fraction of detected ordnance retained after discrimination (give ratio), while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to performance at the demonstrator-supplied level below which all responses are considered noise (i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate).

e. Depending on the density of items that are in a given grid, there exists the possibility of having anomalies within overlapping halos (halo = 1-m diameter) and/or multiple anomalies within halos. In these cases, the following scoring logic is implemented:

(1) For each anomaly supplied by the vendor, the vendor can be only be given credit for finding at most one ordnance item. In other words, if a vendor gives only one anomaly that is within 0.5 meters from six grenades, he will only be given credit for finding one of those six grenades.

(2) In situations where multiple anomalies exist within a single R_{halo}, the anomaly with the strongest response or highest ranking will be assigned to that particular ground truth item. For example, if a vendor supplies two anomalies that are within 0.5 meters from a given ordnance item, and one of the anomalies has a signal level (response level if we are calculating the response stage value, or the discrimination ranking if we are calculating the discrimination stage value) of 0 while another anomaly has a signal level 1, then the anomaly with a signal level of 1 will be given credit for finding that particular GT item. The anomaly with a signal level of 0 will then be free to be possibly attached to another GT item if there is another GT item that is within 0.5 meters from that anomaly.

(3) For overlapping R_{halo} situations, ordnance has precedence over clutter. The anomaly with the strongest response or highest ranking that is closest to the center of a particular GT item gets assigned to that item. Remaining anomalies are retained until all matching is complete. In other words, if a vendor supplies only one anomaly that is within 0.5 meters of both an ordnance and clutter item, the vendor will be given credit for finding the ordnance item. On the other hand, if a vendor supplies only one anomaly that is within 0.5 meters of two ordnance items, then the vendor will be given credit for finding whichever ordnance item is closest to the vendor's anomaly.

(4) Anomalies located within any R_{halo} that do not get associated with a particular GT item are thrown out and are not considered in the analysis. As an example, if a vendor supplies two anomalies that are within 0.5 meters from a GT item, and this is not an overlapping halo situation, then one of the anomalies will be used so that the vendor gets credit for finding this GT item, but the second anomaly will neither be used to give the vendor credit for finding a GT item nor will this item be counted as a background alarm.

(5) All anomalies that are supplied by the vendor that are either outside of the boundary of the active site or are within 1 meter of the boundary of the active site will be thrown out and will not be counted as background alarms nor will they contribute to the vendors P_d or P_{fp}. Likewise, all GT items that are outside of the boundary of the active area or are within 1 meter of the boundary of the active site will be thrown out and will not contribute to the vendor's P_d or P_{fp}. If a vendor supplies an anomaly that is within the active site and more than 1 meter away from the boundary of the active site, and this anomaly is within the halo of a GT item that is closer than 1 meter to the boundary of the active site, but this anomaly is not within the halo of a GT item that is further than 1 meter away from the boundary of the active site, then this anomaly will neither be counted as a background alarm, nor will it contribute to the vendors P_d or P_{fp}.

f. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 4.0 using the earlier version 3.11 rules so results can be compared to surveys done in the blind grid and open field area of the Standardized UXO Test Site.

1.2.2 <u>Scoring Factors</u>

Factors to be measured and evaluated as part of this demonstration include:

a. Response Stage ROC curves:

(1) Probability of Detection (P_d^{res}).

(2) Probability of False Positive (P_{fp}^{res}).

(3) Background Alarm Rate (BAR^{res}).

b. Discrimination Stage ROC curves:

(1) Probability of Detection (P_d^{disc}).

(2) Probability of False Positive (P_{fp}^{disc}).

(3) Background Alarm Rate (BAR^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate (R_{fp}).

(3) Background Alarm Rejection Rate (R_{BA}).

d. Other:

(1) Location accuracy.

(2) Equipment setup, calibration time and corresponding worker-hour requirements.

(3) Survey time and corresponding worker-hour requirements.

(4) Reacquisition/resurvey time and worker-hour requirements (if any).

(5) Downtime due to system malfunctions and maintenance requirements.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

POC: Mr. Ryan North
601-634-3486
ryan.e.north@erdc.usace.army.mil

Address: Engineering Research and Development Center (ERDC)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

2.1.2 System Description (provided by demonstrator)

The EM63 is a commercially available sensor (produced by Geonics, Ltd., of Mississauga, Ontario, Canada, who also produces the EM61). It is a high power, high sensitivity, wide bandwidth full-time domain UXO detector. The EM63 consists of a powerful transmitter that generates a pulsed primary magnetic field which induces eddy currents in nearby metallic objects. The time decay of the currents is accurately measured over a wide dynamic range of time. The output of the main sensor is measured and recorded by the main console at 20 to 30 geometrically spaced time gates, depending on the used repetition rate, covering a time range from 180 µs to 63 ms. The second receiver coil, axially mounted with the main coil, is used for target depth determination. The acquisition is either free running or controlled by wheel odometer or manual fiducial.

The EM63 system consists of three major hardware subsystems:

(1) EM63 Control Console Sub-System.

(2) Antenna Cart Sub-System.

(3) Global Positioning System (GPS) Navigation Sub-System.

The EM63 Control Console Sub-System consists of receiver and transmitter unit, controlled by an integrated field computer. The control console also houses the system battery.

The Antenna Cart Sub-System consists of the transmitter antenna (the 1- by 1-m bottom coil) and receiver coils.

The GPS Navigation Sub-System. Local positioning and georeferencing of the Geonics EM63 system is accomplished using a Trimble 5700 real time kinematic (RTK) GPS system. The Trimble system consists of two receivers that are in radio communication with each other. A roving GPS antenna is mounted in the center of the EM63 coils and 2 meters above the bottom coil. The operator or assistant carries the controller for the roving antenna (fig. 1). The antenna is positioned so that it minimizes any influence on the EM63. The roving GPS system constantly receives corrections to the GPS signal from the base station.

Figure 1. Demonstrator's system, EM63/pushcart.

2.1.3 Data Processing Description (provided by demonstrator)

EM63 and GPS data are merged in real-time in the control console. The EM63 output files will be processed with Geonics' proprietary DAT63W software to convert the files from binary to the American Standard Code for Information Interchange (ASCII) data files that will be imported into Geosoft's Oasis Montaj. No corrections are required for positioning since the GPS antenna is centered with respect to the coils. The EM63 files will be combined in Oasis to create one file per area. The resulting area files exported by Oasis meet the requirements of the raw sensor data that must be delivered at the end of the demonstration. The following processing steps will be performed in Oasis:

(1) Background removal or leveling.

(2) Map generation.

(3) Target picking.

2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook. These submitted data are not included in this report in order to protect GT information.

2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

QA: Four levels of QC checks will be performed: the first day of the project, the beginning of each day, multiple times each day, and whenever equipment is changed. The first day of the project, a 10-meter-long line oriented north to south, with a 3-inch steel sphere at the center, will be laid out. This line will be well marked and used each time the instrument and positioning are tested. Data will be collected on the line with and without navigation equipment attached to the EM63 to test for a direct current (DC) shift from the navigation equipment. Instrument response over the steel sphere will then be tested, as well as a position check and a latency check. The line will be slowly walked in two directions and then the cart will be backed up until it is centered on the sphere. This will set the location of the sphere as well as the instrument response, which will be used every time the equipment is checked.

Each morning functional equipment checks will be performed. All equipment will be visually inspected for damage. After assembling the equipment and powering up, all cable connections will be checked for shorts or broken pinouts. If any shorts or pinouts are found, the broken cable will be marked and removed from service. Some static and instrument response tests will then be performed to ensure that the data are stable when the instrument is in a static position over a marked location. These tests will be performed after the instrument has had sufficient time to warm up.

Every time the batteries are changed, or data are dumped, the instrument test, the positioning test, and the latency test will be repeated. If equipment is changed, all of the previous tests will be repeated.

QC: The 0.5-meter line spacing will be used on all grids and a reading will be recorded every 0.1 meter in-line. The estimated accuracy of the navigation system will be tested when the latency, positioning, and instrument response test is ran over the steel sphere. The peak will be compared while moving with the position established during the first-day QC checks.

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as MicroSoft Word documents at www.uxotestsites.org.

2.2 APG SITE INFORMATION

2.2.1 Location

The APG Active Response Demonstration Site is located within a secured range area of the Aberdeen Area. The Aberdeen Area of APG is located approximately 30 miles northeast of Baltimore at the northern end of the Chesapeake Bay. The Active Response Demonstration Site encompasses 1.98 acres of upland and lowland flats.

2.2.2 Soil Type

According to the soils survey conducted for the entire area of APG in 1998, the test site consists primarily of Elkton Series type soil (ref 2). The Elkton Series consist of very deep, slowly permeable, poorly drained soils. These soils formed in silty aeolin sediments and the underlying loamy alluvial and marine sediments. They are on upland and lowland flats and in depressions of the Mid-Atlantic Coastal Plain. Slopes range from 0 to 2 percent.

ERDC conducted a site-specific analysis in May of 2002 (ref 3). The results basically matched the soil survey mentioned above. Seventy percent of the samples taken were classified as silty loam. The majority (77 percent) of the soil samples had a measured water content between 15 and 30 percent, with the water content decreasing slightly with depth.

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org on the web to view the entire soils description report.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (30 and 31 March and 23, 24, and 26 through 29 April 2004)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total number of hours operated at each site are presented in Table 1.

TABLE 1. AREAS TESTED AND NUMBER OF HOURS

Area	Number of Hours
Calibration lanes	8.33
Active site	28.83

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An APG weather station located approximately 1 mile west of the test site was used to record average temperature and precipitation on a half-hour basis for each day of operation. The temperatures presented in Table 2 represent the average temperature during field operations from 0700 to 1700 hours, while precipitation data represents a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 2. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 04	Average Temperature, ^{o}F	Total Daily Precipitation, in.
30 Mar	41.8	0.04
31 Mar	46.6	0.10
23 Apr	73.8	0.00
24 Apr	66.3	0.15
26 Apr	63.7	0.72
27 Apr	61.0	0.00
28 Apr	51.8	0.00
29 Apr	61.7	0.00

3.3.2 Field Conditions

ERDC surveyed the active site 23, 24, and 26 through 28 April 2004. The weather was seasonable. Rain fell during and prior to testing. This provided muddy conditions for ERDC during the survey.

3.3.3 <u>Soil Moisture</u>

Three soil probes were placed at various locations within the site to capture soil moisture data: blind grid, calibration, mogul, and wooded areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are provided in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 <u>Setup/Mobilization</u>

These activities included initial mobilization and daily equipment preparation and break down. A 2-person crew took 2 hours and 40 minutes to perform the initial setup and mobilization. There were 3 hours and 45 minutes of daily equipment preparation, and end of the day equipment break down lasted 2 hours 25 minutes.

3.4.2 <u>Calibration</u>

ERDC spent a total of 8 hours 20 minutes in the calibration lanes, of which 3 hours and 45 minutes were spent collecting data. While surveying the active site, ERDC spent 2 hours and 40 minutes calibrating equipment.

3.4.3 <u>Downtime Occasions</u>

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, demonstration site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor costs (section 5), except for downtime due to demonstration site issues. Demonstration site issues, while noted in the daily log, are considered nonchargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are discussed in this section and billed to the total site survey area.

3.4.3.1 <u>Equipment/data checks, maintenance</u>. Equipment data checks and maintenance activities accounted for 6 hours and 40 minutes of site usage time. These activities included changing out batteries and routine data checks to ensure the data was being properly recorded/collected. ERDC spent an additional 10 minutes for breaks and lunches.

3.4.3.2 <u>Equipment failure or repair</u>. Three hours and 15 minutes were needed to resolve equipment failures that occurred while surveying the active site. The time was needed to repair the system console.

3.4.3.3 <u>Weather</u>. No weather delays occurred during the survey.

3.4.4 Data Collection

ERDC spent a total time of 28 hours and 50 minutes in the active response site, 12 hours and 35 minutes of which was spent collecting data.

3.4.5 Demobilization

The ERDC survey crew went on to conduct a full demonstration of the site. Therefore, demobilization did not occur until 28 and 29 April 2004. On that day, it took the crew 2 hours and 45 minutes to break down and pack up their equipment.

3.5 PROCESSING TIME

ERDC submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data was provided at a later date.

3.6 DEMONSTRATOR'S FIELD PERSONNEL

Ryan North, Supervisor
Troy Brosten, Data analyst
Eric Smith, Field Support

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

ERDC surveyed in a linear fashion and used 0.5 meters of line spacing. GPS positioning was also used throughout the survey.

3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are provided in Appendix D. Activities pertinent to this specific demonstration are indicated in highlighted text.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

The probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive (P_{fp}) are shown in Figure 2. Both probabilities plotted against their respective BAR are shown in Figure 3, and both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination.

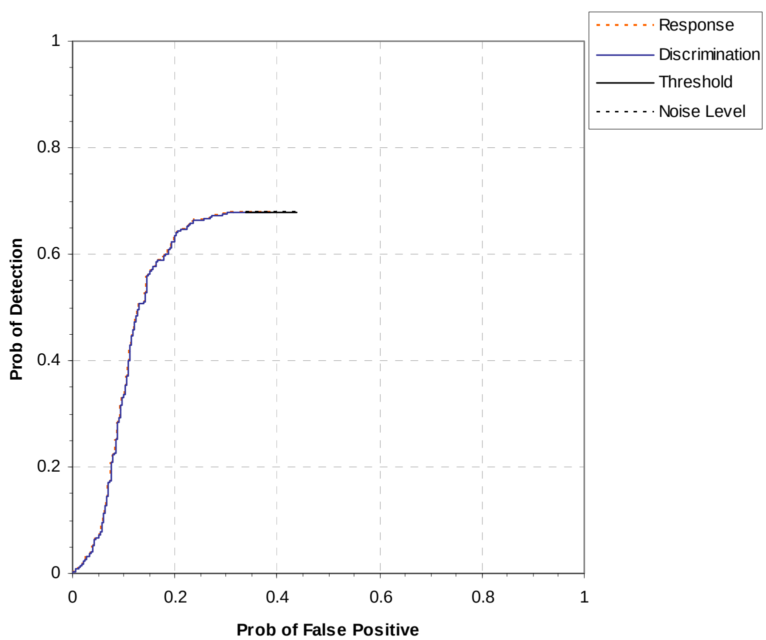

Figure 2. EM63/PUSHCART active response P_d^{res} and P_d^{disc} versus their respective P_{fp} over all ordnance categories combined.

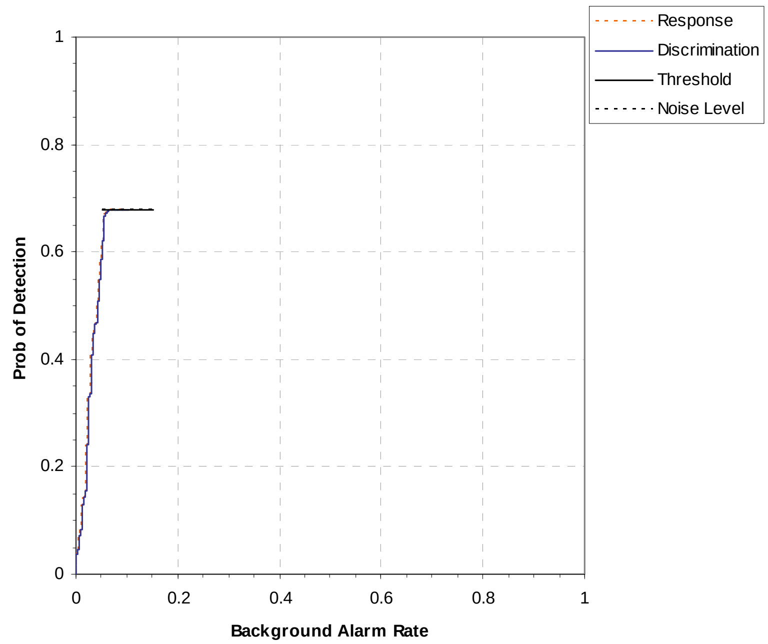

Figure 3. EM63/PUSHCART active response P_d^{res} and P_d^{disc} versus their respective BAR over all ordnance categories combined.

4.2 PERFORMANCE SUMMARIES

The response stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the discrimination stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on P_d and P_{fp} was calculated assuming that the number of detections and false positives are binomially distributed random variables.

Results for the active response test are presented in Table 3 (for cost results, see section 5).

TABLE 3. SUMMARY OF ACTIVESITE RESULTS FOR EM63/PUSHCART

Metric	Overall
RESPONSE STAGE	
P_d	0.68
P_d Low 90% conf	0.64
P_d Upper 90% conf	0.71
P_{fp}	0.39
P_{fp} Low 90% conf	0.37
P_{fp} Upper 90% conf	0.41
BAR	0.10
DISCRIMINATION STAGE	
P_d	0.68
P_d Low 90% conf	0.64
P_d Upper 90% conf	0.71
P_{fp}	0.39
P_{fp} Low 90% conf	0.37
P_{fp} Upper 90% conf	0.41
BAR	0.10

A comparison of the P_d, P_{fp}, and P_{ba}/BAR for both the response stage and discrimination stage for the blind grid, the open field, and the active site is presented in Table 4. P_d^{res} versus the respective P_{fp} over all ordnance categories is shown in Figure 6. P_d^{disc} versus their respective P_{fp} over all ordnance categories is shown in Figure 7 by using horizontal lines to illustrate the performance of the demonstrator at the recommended discrimination threshold levels, defining the subset of targets the demonstrator would recommend digging based on discrimination.

TABLE 4. COMPARISON OF BLIND GRID, OPEN FIELD, AND ACTIVE SITE RESULTS FOR EM63/PUSHCART

Blind Grid		**Open Field**		**Active Site**	
Response Stage		*Response Stage*		*Response Stage*	
P_d	0.75	P_d	0.56	P_d	0.68
P_{fp}	0.79	P_{fp}	0.48	P_{fp}	0.39
P_{ba}	0.13	BAR	0.11	BAR	0.10
Discrimination Stage		*Discrimination Stage*		*Discrimination Stage*	
P_d	0.75	P_d	0.56	P_d	0.68
P_{fp}	0.79	P_{fp}	0.48	P_{fp}	0.39
P_{ba}	0.13	BAR	0.11	BAR	0.10

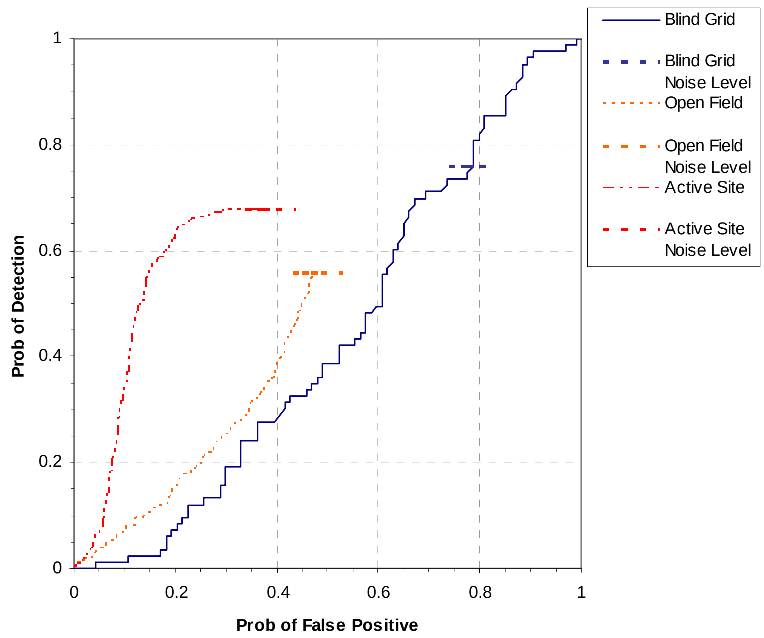

Figure 4. EM63/PUSHCART P_d^{res} stages versus the respective P_{fp} over all ordnance categories combined.

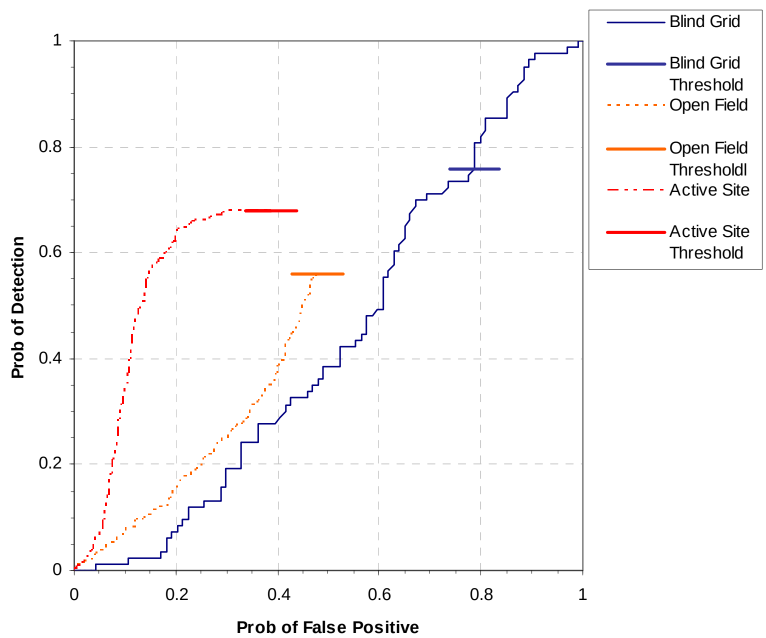

Figure 5. EM63/PUSHCART P_d^{disc} versus the respective P_{fp} over all ordnance categories combined.

4.3 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are presented in Table 5.

TABLE 5. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At operating point	1.00	0.00	0.00
With no loss of P_d	1.00	0.22	0.37

4.4 LOCATION ACCURACY

The mean location error and standard deviations are presented in Table 6. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths could not be accurately measured since the discovered ordnance and clutter were discovered and not emplaced. For the active response, no depth errors are calculated and (X, Y) positions are known from the recovery operation.

TABLE 6. MEAN LOCATION ERROR AND STANDARD DEVIATION (m)

	Mean	Standard Deviation
Northing	0.08	0.16
Easting	0.08	0.16

4.5 STATISTICAL COMPARISONS

Statistical chi-square significance tests were used to compare results between the blind grid and active site and the open field and active site scenarios. The intent of the blind grid and active site comparison is to determine if the feature introduced in each scenario has a degrading effect on the performance of the sensor system. The intent of the open field and active site comparison is to determine if the feature introduced in each scenario has any effect, whether a degradation or an improvement, on the performance of the sensor system. However, any modifications in the UXO sensor system during the test, like changes in the processing or changes in the selection of the operating threshold, will also contribute to performance differences.

The chi-square test for comparison between ratios was used at a significance level of 0.05 to compare blind grid to open field with regard to P_d^{res}, P_d^{disc}, P_{fp}^{res}, and P_{fp}^{disc}, efficiency and rejection rate. These results are presented in Table 7 and Table 8 for the blind grid versus active site and the open field versus active site comparisons, respectively. A detailed explanation and example of the chi-square application is provided in Appendix A.

TABLE 7. CHI-SQUARE RESULTS - BLIND GRID VERSUS ACTIVE SITE

Metric	**Overall**
P_d^{res}	Not significant
P_d^{disc}	Not significant
P_{fp}^{res}	Significant
P_{fp}^{disc}	Significant
Efficiency	Not significant
Rejection rate	Not significant

TABLE 8. CHI-SQUARE RESULTS - OPEN FIELD VERSUS ACTIVE SITE

Metric	**Overall**
P_d^{res}	Significant
P_d^{disc}	Significant
P_{fp}^{res}	Significant
P_{fp}^{disc}	Significant
Efficiency	Not significant
Rejection rate	Not significant

SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated supervisor, the second person was designated data analyst, and the third and following personnel were considered field support. Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, collecting data, downtime due to break/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. The daily activity log is provided in Appendix D. A summary of field activities is provided in Section 3.4.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the calibration lanes as well as field calibrations. Site survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

TABLE 9. ON-SITE LABOR COSTS

	No. People	Hourly Wage	Hours	Cost
Initial Setup				
Supervisor	1	$95.00	2.66	$252.70
Data analyst	1	57.00	2.66	$151.62
Field support		28.50		
Subtotal				**$404.32**
Calibration				
Supervisor	1	$95.00	11.0	$1045.00
Data analyst	1	57.00	11.0	627.00
Field support	1	28.50	11.0	313.50
Subtotal				**$1985.50**
Site Survey				
Supervisor	1	$95.00	28.83	$2738.85
Data analyst	1	57.00	28.83	1643.31
Field support	1	28.50	28.83	821.65
Subtotal				**$5203.81**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
Demobilization				
Supervisor	1	$95.00	2.75	$261.25
Data analyst	1	57.00	2.75	$156.75
Field support	1	28.50	2.75	$78.34
Subtotal				$496.34
Total				**$8089.97**

Notes: Calibration time includes time spent in the calibration lanes as well as calibration before each data run.
Site survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to system maintenance, failure, and weather.

SECTION 6. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within R_{halo} of an emplaced ordnance item.

Munitions and Explosives Of Concern (MEC): Specific categories of military munitions that may pose unique explosive safety risks, including UXO as defined in 10 USC 101(e)(5), DMM as defined in 10 USC 2710(e)(2) and/or munitions constituents (e.g., TNT, RDX) as defined in 10 USC 2710(e)(3) that are present in high enough concentrations to pose an explosive hazard.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site (for the Active site all 'emplaced' items are items discovered during recovery operations and are not strictly emplaced items).

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site (for the Active site all 'emplaced' items are items discovered during recovery operations and are not strictly emplaced items).

R_{halo}: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within R_{halo} of any item (clutter or ordnance), the declaration with the highest signal output within the R_{halo} will be utilized. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the Blind Grid test area.

Discrimination Stage Threshold: The demonstrator selected threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the response stage and discrimination stage. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}) and those that do not correspond to any known item, termed background alarms.

The response stage scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the response stage, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The discrimination stage evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the response stage anomaly list, the discrimination stage list contains the output of the algorithms applied in the discrimination stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide optimum system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/(No. of emplaced ordnance in the test site).

Response Stage False Positive (fp^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of False Positive (P_{fp}^{res}): P_{fp}^{res} = (No. of response-stage false positives)/(No. of emplaced clutter items).

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open field only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note: The quantities P_d^{res}, P_{fp}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{fp}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to nonordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its

maximum (t_{max}) value.[1] Figure A-1 shows how P_d versus P_{fp} and P_d versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

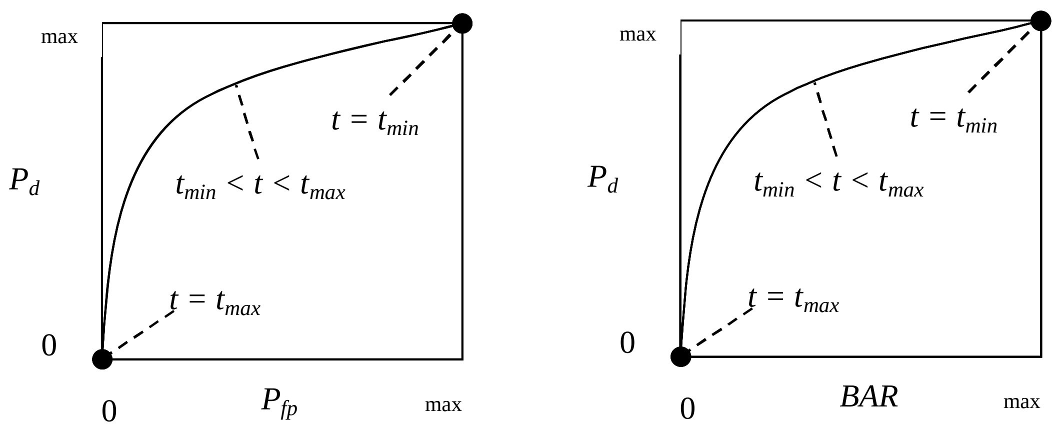

Figure A-1. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from nonordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a pre-determined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the blind grid test sites are true ROC curves.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage ^{t}min) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage ^{t}min). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})])$.

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The chi-square test for differences in probabilities (or 2 by 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 3).

A 2 by 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X’s system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 by 2 contingency table is the chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought for the blind grid versus active site comparison, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 2.71 from the chi-square distribution with one degree of freedom. For the open field versus active site comparison, there is no assumption of a degraded performance for either site. Therefore, a two-sided test is performed to test for a significant difference in performance in either direction. Using the same significance level of 0.05, the critical decision limit is set to 3.84 from the chi-square distribution with one degree of freedom. For both tests, the value obtained from the chi-square distribution is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions

tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

	Blind grid	Open field	Moguls
P_d^{res}	100/100 = 1.0	8/10 = .80	20/33 = .61
P_d^{disc}	80/100 = 0.80	6/10 = .60	8/33 = .24

P_d^{res}: blind grid versus open field. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

P_d^{disc}: blind grid versus open field. Using the example data above to compare probabilities of detection in the discrimination stage, 80 out of 100 emplaced ordnance items were correctly discriminated as ordnance in blind grid testing while 6 ordnance out of 10 emplaced were correctly discriminated as such in open field-testing. Those four values are used to calculate a test statistic of 1.12. Since the test statistic is less than the critical value of 2.71, the two discrimination stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{res}: open field versus moguls. Using the example data above to compare probabilities of detection in the response stage, 8 out of 10 and 20 out of 33 are used to calculate a test statistic of 0.56. Since the test statistic is less than the critical value of 2.71, the two response stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{disc}: open field versus moguls. Using the example data above to compare probabilities of detection in the discrimination stage, 6 out of 10 and 8 out of 33 are used to calculate a test statistic of 2.98. Since the test statistic is greater than the critical value of 2.71, the smaller discrimination stage detection rate is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the ability of demonstrator X to correctly discriminate seems to have been degraded by the mogul terrain relative to results from the flat open field using the same system.

APPENDIX B.   DAILY WEATHER LOGS

Date, 2004	Time	Average Temperature, ^{O}F	Average Precipitation, in.
30 Mar	0700	37.6	0
	0800	38.3	0
	0900	39.3	0
	1000	40.3	0
	1100	41.3	0
	1200	42.0	0
	1300	43.2	0
	1400	44.6	0
	1500	44.6	0
	1600	44.4	0
	1700	44.7	0
31 Mar	0700	42.9	0
	0800	43.3	0
	0900	44.2	0
	1000	45.0	0
	1100	46.0	0
	1200	47.4	0
	1300	48.0	0
	1400	48.4	0
	1500	48.8	0
	1600	49.1	0
	1700	49.9	0
23 Apr	0700	60.8	0
	0800	65.4	0
	0900	69.5	0
	1000	72.6	0
	1100	74.8	0
	1200	76.0	0
	1300	77.2	0
	1400	77.7	0
	1500	80.4	0
	1600	79.6	0
	1700	77.3	0
24 Apr	0700	56.4	0
	0800	60.1	0
	0900	62.9	0
	1000	64.5	0
	1100	66.0	0
	1200	67.4	0
	1300	68.6	0
	1400	69.6	0
	1500	70.8	0
	1600	71.3	0
	1700	71.5	0

Date, 2004	Time	Average Temperature, ^{O}F	Average Precipitation, in.
26 Apr	0700	63.4	0
	0800	64.7	0
	0900	66.3	0
	1000	66.5	0
	1100	66.9	0
	1200	63.0	0.15
	1300	62.0	0
	1400	62.4	0.01
	1500	62.4	0.01
	1600	61.5	0.02
	1700	61.1	0.05
27 Apr	0700	52.6	0
	0800	57.7	0
	0900	60.5	0
	1000	62.6	0
	1100	63.2	0
	1200	64.3	0
	1300	64.3	0
	1400	64.9	0
	1500	63.4	0
	1600	60.6	0
	1700	57.4	0
28 Apr	0700	41.5	0
	0800	43.5	0
	0900	45.5	0
	1000	47.8	0
	1100	50.3	0
	1200	52.5	0
	1300	54.1	0
	1400	56.4	0
	1500	57.9	0
	1600	59.6	0
	1700	60.5	0
29 Apr	0700	54.0	0
	0800	60.1	0
	0900	62.9	0
	1000	64.6	0
	1100	67.1	0

APPENDIX C. SOIL MOISTURE

Date: 30 Mar 2004			
Times: No AM readings, 1600 hrs (PM)			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet area	0 to 6	No readings taken	No readings taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration lanes	0 to 6		39.8
	6 to 12		37.7
	12 to 24		0.9
	24 to 36		4.5
	36 to 48		4.9
Blind grid/moguls	0 to 6		No readings taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

Date: 31Mar 2004			
Times: 0715hrs (AM), 1600 hrs (PM)			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet area	0 to 6	No readings taken	No readings taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded area	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Calibration lanes	0 to 6	39.2	
	6 to 12	37.5	
	12 to 24	0.9	
	24 to 36	4.7	
	36 to 48	5.2	
Blind grid/moguls	0 to 6	No readings taken	4.9
	6 to 12		9.8
	12 to 24		34.9
	24 to 36		36.2
	36 to 48		38.9

Date: 23 Apr 2004			
Times: 0800 (AM), No readings taken (PM)			
Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet area	0 to 6	79.2	No readings taken
	6 to 12	78.7	
	12 to 24	70.2	
	24 to 36	53.5	
	36 to 48	49.5	
Wooded area	0 to 6	No readings taken	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open field	0 to 6	12.2	
	6 to 12	3.2	
	12 to 24	15.8	
	24 to 36	21.2	
	36 to 48	27.5	
Calibration lanes	0 to 6	No readings taken	
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Blind grid/moguls	0 to 6		
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		

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APPENDIX D. DAILY ACTIVITY LOG

Date, 04	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
30 Mar	2	CALIBRATION LANES	1030	1200	90	INITIAL MOBILIZATION	INITIAL MOBILIZATION	GPS	LINEAR	CLOUDY	MUDDY
	2	CALIBRATION LANES	1200	1230	30	LUNCH/BREAK	LUNCH/BREAK	GPS	LINEAR	CLOUDY	MUDDY
	2	CALIBRATION LANES	1230	1340	70	INITIAL MOBILIZATION	INITIAL MOBILIZATION	GPS	LINEAR	CLOUDY	MUDDY
	2	CALIBRATION LANES	1340	1350	10	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	CLOUDY	MUDDY
	2	CALIBRATION LANES	1350	1540	110	COLLECT DATA	COLLECT DATA	GPS	LINEAR	CLOUDY	MUDDY
	2	CALIBRATION LANES	1540	1550	10	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	CLOUDY	MUDDY
	2	CALIBRATION LANES	1550	1620	30	DAILY START/STOP	END OF DAILY OPERATIONS	GPS	LINEAR	CLOUDY	MUDDY
31 Mar	3	CALIBRATION LANES	800	925	85	DAILY START/STOP	START OF DAILY OPERATIONS	GPS	LINEAR	CLOUDY	MUDDY
	3	CALIBRATION LANES	925	1120	115	COLLECT DATA	COLLECT DATA	GPS	LINEAR	CLOUDY	MUDDY
	3	CALIBRATION LANES	1120	1140	20	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	CLOUDY	MUDDY
	3	CALIBRATION LANES	1140	1310	90	LUNCH/BREAK	LUNCH/BREAK	GPS	LINEAR	CLOUDY	MUDDY
23 Apr	3	ACTIVE SITE	1315	1445	90	DAILY START/STOP	SET UP GRIDS	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1445	1545	60	DAILY START/STOP	END OF DAILY OPERATIONS	GPS	LINEAR	SUNNY	MUDDY

Date, 04	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
24 Apr	3	ACTIVE SITE	745	815	30	DAILY START/STOP	START OF DAILY OPERATIONS	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	815	825	10	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	825	1005	100	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1005	1010	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1010	1055	45	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1055	1110	15	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1110	1215	65	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1215	1225	10	LUNCH/BREAK	LUNCH/BREAK	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1225	1330	65	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1330	1335	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1335	1415	40	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1415	1455	40	DAILY START/STOP	END OF DAILY OPERATIONS	GPS	LINEAR	SUNNY	MUDDY
26 Apr	3	ACTIVE SITE	800	830	30	DAILY START/STOP	START OF DAILY OPERATIONS	GPS	LINEAR	CLOUDY	MUDDY
	3	ACTIVE SITE	830	1145	195	EQUIPMENT FAILURE	CONSOLE PROBLEM	GPS	LINEAR	CLOUDY	MUDDY

Date, 04	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
26 Apr	3	ACTIVE SITE	1145	1210	25	DAILY START/STOP	END OF DAILY OPERATIONS	GPS	LINEAR	CLOUDY	MUDDY
27 Apr	3	ACTIVE SITE	955	1050	55	DAILY START/STOP	START OF DAILY OPERATIONS	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1050	1105	15	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1105	1205	60	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1205	1305	60	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1305	1315	10	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1315	1420	65	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1420	1425	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1425	1450	25	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1450	1500	10	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1500	1520	20	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1520	1620	60	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1620	1630	10	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1630	1730	60	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY

Date, 04	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
27 Apr	3	ACTIVE SITE	1730	1735	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1735	1805	30	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1805	1825	20	DAILY START/STOP	END OF DAILY OPERATIONS	GPS	LINEAR	SUNNY	MUDDY
28 Apr	3	ACTIVE SITE	740	800	20	DAILY START/STOP	START OF DAILY OPERATIONS	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	800	810	10	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	810	915	65	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	915	920	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	920	940	20	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	940	950	10	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	950	1040	50	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1040	1045	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1045	1115	30	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1115	1125	10	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1125	1240	75	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY

Date, 04	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
28 Apr	3	ACTIVE SITE	1240	1245	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1245	1305	20	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1305	1310	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1310	1400	50	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1400	1405	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1405	1440	35	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1440	1445	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1445	1600	75	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1600	1605	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1605	1620	15	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1620	1630	10	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1630	1735	65	COLLECT DATA	COLLECT DATA	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1735	1740	5	CALIBRATE	CALIBRATE WITH METAL RING	GPS	LINEAR	SUNNY	MUDDY
	3	ACTIVE SITE	1740	1800	20	DOWNTIME MAINTENANCE CHECK	DOWNLOAD/CHECK DATA	GPS	LINEAR	SUNNY	MUDDY

Date, 04	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Pattern	Field Conditions	
28 Apr	3	OPEN FIELD	1800	1845	45	DEMOBILIZATION	DEMOBILIZATION	GPS	LINEAR	SUNNY	MUDDY
29 Apr	3	OPEN FIELD	730	930	120	DEMOBILIZATION	DEMOBILIZATION	GPS	LINEAR	SUNNY	MUDDY

APPENDIX E.   REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

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APPENDIX F. ABBREVIATIONS

ADST	=	Aberdeen Data Services Team
AEC	=	U.S. Army Environmental Center
APG	=	Aberdeen Proving Ground
ASCII	=	American Standard Code for Information Interchange.
ATC	=	U.S. Army Aberdeen Test Center
ATSS	=	Aberdeen Test and Support Services
BAR	=	Background Alarm Rate
DC	=	direct current
DMM	=	discarded military munitions
EQT	=	Army Environmental Quality Technology Program
ERDC	=	U.S. Army Corps of Engineers Engineering Research and Development Center
ESTCP	=	Environmental Security Technology Certification Program
GPS	=	Global Positioning System
GT	=	ground truth
HDSD	=	Homeland Defense and Sustainment Division
MEC	=	munitions and explosives of concern
MTADS	=	Multiple Towed Array Detection System
NRL	=	Naval Research Lab
POC	=	point of contact
QA	=	quality assurance
QC	=	quality control
ROC	=	receiver-operating characteristic
RTK	=	real time kinematic
SERDP	=	Strategic Environmental Research and Development Program
USAEC	=	U.S. Army Environmental Command
UXO	=	unexploded ordnance

APPENDIX G.   DISTRIBUTION LIST

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